The Role of Biologically-Generated Turbulence in the Upper Ocean

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LONG TERM GOALS

Our interests are in oceanic processes that contribute to stirring and mixing in order to understand their impact on larger scales. This includes phenomena ranging from the mesoscale (10-100 km) to the microscale (1 cm). Of particular interest is how different processes interact to produce turbulence and mixing.

OBJECTIVES

Recent work based on the energetics of ocean biology suggests that schooling marine organisms can generate turbulent dissipation rates $\varepsilon \sim 10^{-5}$ W kg^{-1} (Huntley and Zhou 2004) with as much as 1 TW available globally to generate ocean turbulence (Munk 1966; Dewar *et al*. 2006). Measurements in Saanich Inlet (Fig. 1; Kunze *et al.* 2006) were the first to reveal intense (10^{-5} - 10^{-4} W kg^{-1}) turbulent bursts coinciding with dawn and dusk vertical migrations of krill swarms. Lasting only 10-15 minutes, these events were nevertheless of sufficient intensity to increase daily-average mixing in the inlet by 2-3 orders of magnitude. This mechanism is potentially important for mixing nutrients and gases through the transition layer at the base of the surface mixed-layer. But it is poorly understood. Turbulence dissipation does not always arise in association with migration of backscatter layers (Rippeth *et al*. 2007) and mixing is not always associated with dissipation (Gregg and Horne 2008). A mixing event of the magnitude observed in Saanich Inlet need only occur a few times per year to produce as much mixing as deep-ocean internal waves. Consequently, despite the very patchy nature of high-density schools and swarms, biologically-generated turbulence may play an important mixing role in the ocean and deserves further study. We seek to determine (i) how frequently vertically migrating backscatter layers lead to turbulence and turbulent mixing, (ii) under what conditions (season, cloud-cover, lunar cycle, backscatter intensity, backscatter migration speed, etc) favor the production of turbulence.

APPROACH

We propose to collect time-series measurements of the acoustic backscatter layer and turbulence signals in order to evaluate the role of biologically-generated turbulence. Measurements will be made in Saanich Inlet, BC on a mooring maintained by the VENUS observatory, and at open-ocean sites of opportunity. Migration of the backscatter layer is already being monitored acoustically in the inlet. We will instrument a mooring to infer turbulence with a combination of high-frequency acoustic

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14. ABSTRACT
Recent work based on the energetics of ocean biology suggests that schooling marine organisms can generate turbulent dissipation rates ε ~ 10?5 W kg?1 (Huntley and Zhou 2004) with as much as 1 TW available globally to generate ocean turbulence (Munk 1966; Dewar et al. 2006). Measurements in Saanich Inlet (Fig. 1; Kunze et al. 2006) were the first to reveal intense (10?5 - 10?4 W kg?1) turbulent bursts coinciding with dawn and dusk vertical migrations of krill swarms. Lasting only 10-15 minutes, these events were nevertheless of sufficient intensity to increase daily-average mixing in the inlet by 23 orders of magnitude. T

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sensors to estimate the dissipation rate and finescale *T-S* sensors to infer Thorpe overturning scales. In situ microstructure, acoustic and biological data will be sampled from the University of Victoria's day boat R/V Strickland.

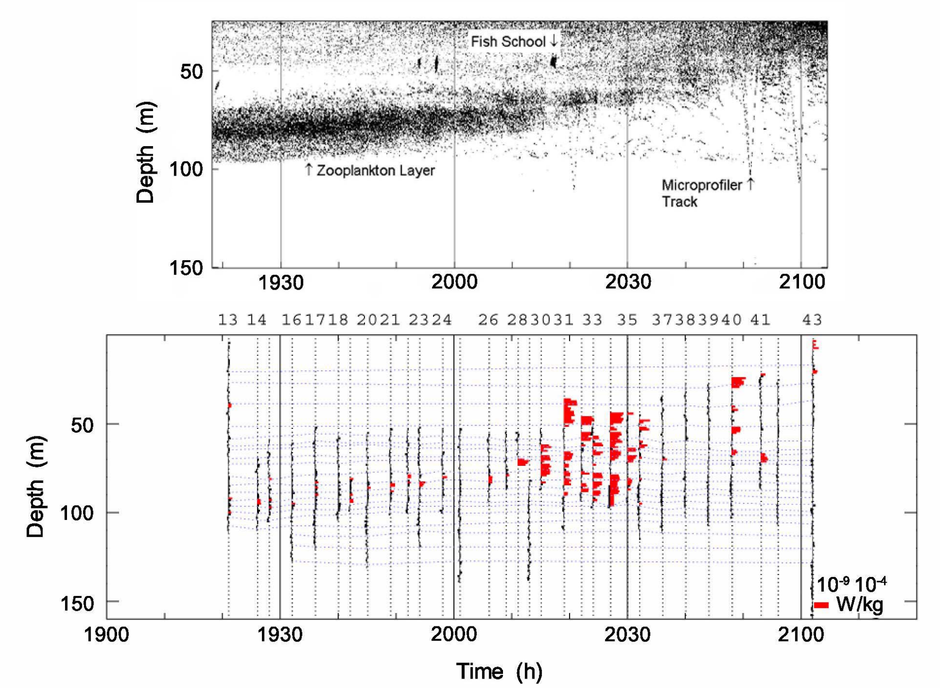

Figure 1: Profile time-series of acoustic backscatter (upper panel) and turbulent kinetic energy dissipation rate ε (lower panel) in Saanich Inlet, BC, during dusk of 28 April 2005. The dotted horizontal lines in the lower panel correspond to density surfaces. Sunset was around 2000 h. During daylight hours, the backscatter layer is concentrated between 70-100 m depth and dissipation rates are O(10^{-9} W kg^{-1}). Shortly after dusk, the layer becomes more dispersed and migrates upward into the surface layer (2015-2045 h). During 15 minutes of this migration, dissipation rates exceed 10^{-5} W kg^{-1}.

In addition, we will take advantage of any opportunity when we are at sea to look for this process. For example, shipboard measurements of acoustic backscatter and turbulence have been made at Ocean Station Papa, during the AESOP DRI and during an August 2008 cruise to study the turbulent boundary layer in Monterey Submarine Canyon.

Collaboration with the VENUS project also allows participation in the Lateral Mixing DRI using a new towed horizontal microstructure profiler to characterize diapycnal turbulence levels along upper pycnocline isopycnals in support of a dye-release experiment.

WORK COMPLETED

As funding just arrived a few months ago, new measurements have not yet been collected. A Tucker trawl has been purchased for biological sampling and a winch ordered to allow tow-yoing of the horizontal microstructure profiler. Masters student Shani Rousseau is using a statistical approach to separate turbulent dissipation rates associated with finescale shear from those associated with acoustic backscatter signals.

RESULTS

Even in the energetic open-ocean OSP site, some of the turbulence signal appears to be associated with backscatter layers rather than internal wave shear.

IMPACT/APPLICATION

Reporting turbulent mixing associated with migrating krill swarms proved controversial. Rippeth *et al*. (2007) explored 11 summer data sets from the continental shelf west of the British Isles, finding no evidence of elevated dissipation rates associated with vertical migration of the acoustic backscatter layer. Visser (2007) challenged the very notion that 1-cm krill could produce turbulence mixing. Although this was addressed in our original Science paper, we submitted a letter to reiterate the that dissipation signals we reported coincided with a broadband spectrum, 1-10 m density overturns, and signals in temperature and conductivity microstructure, all of which point to mixing. The generation of larger scales by swimming krill suggests aggregate behavior. Gregg and Horne (2008) found intense turbulent kinetic energy dissipation rates associated with schools of small fish in Monterey Bay. However, these were not accompanied by temperature microstructure signals so mixing was weak.

RELATED PROJECTS

The PIs are co-PIs on a VENUS infrastructure proposal to be submitted to the Canada Foundation for Innovation that will support part of the biological turbulence measurements in Saanich Inlet.

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PUBLICATIONS

N/A